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Invention: FLUID FLOW AMOUNT MEASURING APPARATUS RESPONSIVE TO FLUID FLOW IN FORWARD AND REVERSE DIRECTIONS

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SPECIFICATION

FLUID FLOW AMOUNT MEASURING APPARATUS RESPONSIVE TO FLUID FLOW IN FORWARD AND REVERSE DIRECTIONS

CROSS REFERENCE TO RELATED APPLICATION

This application relates to and incorporates herein by reference Japanese Patent Applications No. 10-299353 filed on October 21, 1998 and No. 11-290517 filed on October 13, 1999.

BACKGROUND OF THE INVENTION

1. Field of the Invention

Sub A1

The present invention relates to a flow amount measuring apparatus for measuring a fluid flow amount.

2. Related Art

Sub A2

A thermal-type flow amount meter is used as a flow amount measuring apparatus to measure an intake air amount of an internal combustion engine of automotive vehicles or the like. In the engine of not more than four cylinders, intake air pulsation increases when it is in a low rotational speed and high load condition. When opening periods of an intake valve and an exhaust valve overlap when the intake air flow is pulsating, the intake air is like to flow in reverse through the intake valve when a piston moves upward. The air flowing in reverse also is detected as the intake air flow amount. As a result, the intake air flow amount which is sucked into a combustion chamber cannot be detected accurately.

A flow amount meter disclosed in JP-B2-62-14705 measures an intake air flow amount by correcting an average flow amount

Sub. A2 Cont'd.

based on engine operating condition parameters such as an engine rotational speed and a throttle opening degree, so that the fluid flow amount may be measured in consideration of the direction of fluid flow. However, the intake air flow amount cannot be measured with high accuracy, because the intake air pulsation accompanied by the reverse flow cannot be simply determined from the engine rotational speed and the throttle opening degree.

A flow amount meter disclosed in JP-A-61-213728 determines that an intake air flow direction is reversed when a plurality of singular points of a function appears in detected flow amount values. It is however difficult to accurately detect the reversal of the intake air flow from the detection of the singular points of a function, because the pulsation in the intake air flow is influenced largely by the types of engines and intake air duct configurations.

A flow amount meter disclosed in JP-A-1-185416 detects an intake air flow direction from a difference between detection signals of two heaters disposed at an upstream side and a down stream side of a planar substrate. However, a control circuit construction is complicated, because two control circuits are required to detect signals from each heater. In addition, a temperature change rate of each heater at the time of heating operation may differ from each other, because it is difficult to match control constants of the two control circuits. Errors will occur in the difference between the temperatures of the heaters, thus disabling an accurate detection of the intake air flow direction.

Flow amount meters and flow speed sensors disclosed in JP-A-8-14978, JP-A-60-142268 and JP-A-6-160142 detects an intake air flow direction from a difference between detection signals of two temperature sensors which are disposed at an upstream side and a downstream side of a heater. However, a sensing part including an intake air temperature sensor becomes large and the heat capacity of the sensing part increases, because the temperature sensors are disposed upstream and downstream the heater. As a result, the detection sensitivity and responsiveness of the flow amount meter will be lessened.

Sub. A3 cont.

A flow amount meter disclosed in JP-A-10-62220 expands a measurable range and decreases a ratio of noise relative to an output by arranging a heater to surround a group of temperature measuring resistors and increasing a difference between the temperatures of temperature measuring resistors of the group disposed at an upstream side and a downstream side in the group with respect to a fluid flow direction. However, a sensing part becomes large and the heat capacity of the sensing part increases, because the heater surrounds the group of the temperature measuring resistors. As a result, the detection sensitivity and responsiveness of the flow amount meter will be lessened.

SUMMARY OF THE INVENTION

It is an object of the invention to provide a small-sized flow amount measuring apparatus which detects a flow amount with high accuracy irrespective of fluid flow direction.

According to the present invention, a heater is strip-

shaped in a manner that each strip turns at a plurality of points and has a width in a flow direction. The temperature of the heater is controlled to a reference temperature determined in correspondence with a temperature detected by a fluid temperature detector. A flow amount detector is disposed at only one of an upstream side and a downstream side of the heater with respect to one fluid flow direction, so that a fluid flow amount varying with a fluid flow direction is detected from the temperature detected by the flow amount detector.

Sub. A3 con

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description made with reference to the accompanying drawings. In the drawings:

Fig. 1A is a plan view showing a flow amount measuring apparatus according to a first embodiment of the present invention, and Fig. 1B is a sectional view showing the flow amount measuring apparatus along line IB-IB in Fig. 1A;

Fig. 2 is a circuit diagram showing an equivalent circuit of the flow amount measuring apparatus according to the first embodiment;

Fig. 3 is a graph showing a temperature distribution in the cases of an air flow in a forward direction and a reverse direction in the first embodiment;

Fig. 4 is a characteristic graph showing a relation between the air flow and a flow amount detector in the case of the air

flow in the forward direction and the reverse direction in the first embodiment;

Fig. 5 A is a plan view showing a flow amount measuring apparatus according to a comparative example, and Fig. 5B is a sectional view showing the flow amount measuring apparatus along line VB-VB in Fig. 5A;

Fig. 6 is a graph showing a temperature distribution in the cases of an air flow in a forward direction and a reverse direction in the comparative example;

Fig. 7 is a characteristic diagram showing a relation between the air flow and a flow amount detector in the case of the air flow in the forward direction and the reverse direction in the comparative example;

Fig. 8 is a plan view showing a flow amount measuring apparatus according to a second embodiment of the present invention;

Fig. 9A is a plan view showing a flow amount measuring apparatus according to a third embodiment of the present invention, and Fig. 9B is a sectional view showing the flow amount measuring apparatus taken along line IXB-IXB in Fig. 9A;

Fig. 10A is a plan view showing a flow amount measuring apparatus according to a fourth embodiment of the present invention, and Fig. 10B is a sectional view showing the flow amount measuring apparatus along line XB-XB in Fig. 10A;

Fig. 11 is a plan view showing a flow amount measuring apparatus according to a fifth embodiment of the present invention;

Fig. 12A is a plan view showing a flow amount measuring

apparatus according to a sixth embodiment of the present invention, and Fig. 12B is a sectional view of the flow amount measuring apparatus along line XIIB-XIIB in Fig. 12A;

Fig. 13 is a circuit diagram showing an equivalent circuit of the flow amount measuring apparatus according to the sixth embodiment;

Fig. 14 is a diagram showing an equivalent circuit of the flow amount measuring apparatus according to a seventh embodiment of the present invention; and

Fig. 15 is a diagram showing an equivalent circuit of a flow amount measuring apparatus according to an eighth embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention will be described with reference to various embodiments which are applied to an intake air amount measuring apparatus for internal combustion engines. The same reference numerals designate the same construction.

(First Embodiment)

Referring to Figs. 1A and 1B, a flow amount detecting unit 10 is disposed in an engine intake duct (not shown). The flow amount detecting unit 10 comprises a semiconductor substrate 11 made of a silicon or the like. A cavity 11a is formed in the semiconductor 1 at a location where a flow amount detector 21 and a heater 30 are formed. An insulating film 12 covers a top surface of the semiconductor substrate 11 including the cavity 11a. The cavity 11a is formed by an anisotropic etching from a bottom surface

higher than that detected by the intake air temperature detector 20.

In Fig. 2, a circuit which includes the flow amount detector 21, a resistor 45 having a fixed resistance, an amplifier 46 and the like is for outputting an amplified potential which varies with a ratio of resistances of the flow amount detector 21 and the resistor 45. As the flow amount detector 21 changes its temperature and hence its resistance in accordance with an intake air flow amount and an intake air flow direction, the output of the amplifier 46 responsively changes.

A relation among a temperature distribution in the heater 30, a detection temperature of the flow amount detector 21 and the reference temperature are shown in Fig. 3. The temperature in the heater 30 at the upstream side of the intake air flow decreases below the reference temperature, because the intake air flow in the forward direction cools the upstream side of the heater 30 more than the downstream side. The total resistance of the heater 30 lowers, because the resistance at the upstream side decreases when the temperature of the upstream side lowers. The electrical current supplied to the heater 30 increases to raise the decreased total resistance, and the temperature at the downstream side of the intake air flow rises above the reference temperature. The total resistance of the heater 30 increases, because the resistance at the downstream side increases with the increase in the temperature at the downstream side. The temperature at the upstream side of the heater 30 is still maintained below the reference temperature, because the intake

side of the semiconductor substrate 11 to a boundary surface with the insulating film 12. An intake air temperature detector 20, flow amount detector 21 and heater 30 are formed in this order on the insulating film 12 from the upstream side (left side in the figures) in a forward direction in which the intake air normally flows to be sucked into combustion chambers (not shown). The intake air temperature detector 20 as a fluid temperature detector is a resistor which changes its resistance in response to the intake air temperature thereby detecting the temperature of the intake air flowing therethrough. The heater 30 is a heat-generating type resistor and is controlled, by a bridge circuit shown in Fig. 2, to a reference temperature which is a predetermined temperature higher than that of the intake air temperature detected by the intake air temperature detector 20. The intake air temperature detector 20 is disposed at an upstream position away from the heater 30 so that the heat of the heater 30 does not influence the temperature detection operation of the intake air temperature detector 20. The flow amount detector 21 is a resistor and disposed at the upstream side of the heater 30 with respect to the forward direction of the intake air flow. The flow amount detector 21 also changes its resistance to detect the intake air flow amount passing therethrough.

As shown in Fig. 1A, the heater 30 is a thin strip type and turns at a plurality of locations in a manner that each strip cross perpendicularly to the intake air flow direction. It has a predetermined width in the intake air flow direction. Terminals 35 are provided to electrically connect the intake air temperature

detector 20, the flow amount detector 21 and the heater 30 with an external electrical circuit. The intake air temperature detector 20, the flow amount detector 21 and the heater 30 are covered with an insulating film 13.

The flow amount detecting unit 10 shown in Fig. 1 is connected to an external electrical circuit as shown in Fig. 2. The intake air temperature detector 20 and the heater 30 form a bridge circuit with resistors 41 and 42 of fixed resistances. The resistance of each resistor of the bridge circuit is determined so that the temperature of the heater 30 is maintained at a reference temperature which is predetermined temperature higher than that detected by the intake air temperature detector 20. The reference temperature increases and decreases in accordance with the intake air temperature detected by the intake air temperature detector 20.

When the temperature of the heater 30 becomes lower than the reference temperature and its resistance decreases, a potential difference appears between junctions 50 and 51 in the bridge circuit. A comparator 43 produces a high level output to turn on a transistor 44 and supply an electrical current to the heater 30 so that the temperature of the heater 30 rises. When the temperature of the heater 30 reaches the reference temperature and its resistance increases, the transistor 44 turns off in response to a low level output of the comparator 43 to interrupt the electrical current supplied to the heater 30. The temperature of the heater 30 is set, by the bridge circuit as constructed above, to the reference temperature which is predetermined temperature

air flow continues to cool the upstream side. The heat transfer path along which the heat is transferred from the downstream side to the upstream side of the intake air flow in the heater 30 is long, and the heat is not transferred quickly from the downstream side to the upstream side of the intake air flow. As a result, the temperatures at the upstream side and the downstream side of the intake air flow in the heater 30 continues to be lower and higher than the reference temperature, respectively.

The flow amount detector 21 is located close to the upstream side of the intake air flow of the heater 30 with respect to the forward direction of the intake air flow so that the temperature detected by the flow amount detector 21 becomes substantially equal to the temperature of the upstream side of the heater 30. That is, the detection temperature of the flow amount detector 21 is lower and higher than the reference temperature when the intake air flows in the forward direction and in the reverse direction, respectively. The larger difference between the detection temperature of the flow amount detector 21 and the reference temperature means the larger intake air flow amount irrespective of the intake air flow direction. Changes in the detection temperature of the flow amount detector 21 with respect to the intake air flow direction and the intake air flow amount are shown in Fig. 4.

Here, the characteristics of Fig. 4 showing changes in the detection temperature of the flow amount detector 21 changes with the intake air temperature, because the reference temperature changes with the detection temperature of the intake air

temperature detector 20, that is, the intake air temperature. The control circuit shown in Fig. 2 thus detects the intake air flow amount while responding to the intake air flow direction under the condition that the intake air temperature does not change. Even under the condition that the intake air temperature changes, the intake air flow amount responsive to the intake air flow direction can be measured by, for instance, varying the other input potential of the amplifier 46, to which the potential of a junction 52 is applied, in response to the detection temperature of the intake air temperature detector 20 or the reference temperature of the heater 30. That is, the intake air flow amount can be measured irrespective of changes in the intake air temperature by comparing the temperature detected by the flow amount detector 21 with the detection temperature of the intake air temperature detector 20 or the reference temperature of the heater 30. Because the reference temperature is set to be predetermined temperature higher than the detection temperature of the intake air temperature detector 20, the intake air flow amount responsive to the intake air flow direction can be measured by comparing either one of the temperatures with the detection temperature of the flow amount detector 21. It is also possible to measure the intake air flow amount by applying the potential signals of the junctions 50 and 52 to an ECU and retrieving a map data in the ECU.

Here, a flow amount meter unit in which flow amount detector are disposed upstream and downstream a heater is described for comparison with the first embodiment. As shown in Figs. 5A and 5B, in a unit 100, an intake air temperature detector 110, a flow

amount detector 112, a heater 111 and a flow amount detector 113 are disposed on a substrate 101 from the upstream side in the forward direction of intake air flow. The temperature of the heater 111 is controlled to be a predetermined temperature higher than that detected by the intake air temperature detector 110.

As shown in Fig. 6, as long as the intake air flows in the forward direction, the detection temperature of the flow amount detector 112 located upstream the heater 111 is lower than the detection temperature of the flow amount detector 113 located downstream the heater 111. Further, as long as the intake air flows in the reverse direction, the detection temperature of the flow amount detector 113 located upstream the heater 111 in the reverse direction is lower than the detection temperature of the flow amount detector 112 located downstream the heater 111. The heater 111 turns only at one point and its width in the intake air flow direction is narrow. As a result, there occurs substantially no difference in temperatures in the intake air flow direction and the temperature is set uniformly over the entire area. Therefore, the detection temperature of the flow amount detectors 112 and 113 are slightly lower than the reference temperature set in the heater 111, because of being cooled by the intake air flow.

The relation of the detection temperature of the flow amount detector 112 relative to the intake air flow direction and the intake air flow amount is shown in Fig. 7. The detection temperature indicates the temperature of the flow amount detector 112 and the flow amount detector 113 when the intake air flows in the forward direction and in the reverse direction, respectively.

As understood from Fig. 7, the difference between the temperatures detected by the flow amount detectors is small, because the heater 111 has no substantial temperature difference in the intake air flow direction. Therefore, the intake air flow amount cannot be measured with high accuracy when the intake air flow amount is small. Further, the detecting unit must be sized large to dispose the flow amount detectors 112 and 113 at the upstream side and the downstream side of the heater 111, respectively. As a result, the heat capacity of the unit 100 becomes large, and the detection sensitivity and the responsiveness become low.

According to the first embodiment, however, the heater 30 turns at plural points to cross in a direction perpendicular to the intake air flow and has the predetermined width in the intake air flow direction so that the length of the heat transfer path is extended in the intake air flow direction. As a result, the temperature at the upstream side in the heater 30 in the air flow direction becomes lower than the reference temperature because of cooling by the intake air flow. The temperature at the downstream side in the heater 30 in the air flow direction is increased above the reference temperature to maintain the reference temperature. This condition is maintained. The flow amount detecting unit 10 is thus sized small and its heat capacity is decreased, because the intake air flow amount and the intake air flow direction are detected by comparing the detection temperature of the flow amount detector 21 and the reference temperature. In addition, because the difference between the

detection temperature of the flow amount detector 21 and the reference temperature is made large, the intake air flow amount and the intake air flow direction are detected with high sensitivity and responsiveness even when changes in the temperature and the flow amount are small.

(Second Embodiment)

In a second embodiment shown in Fig. 8, a strip of heater 31 is turned at a plurality of points so that each strip extends in the intake air flow direction. In this heater 31, the temperatures at the upstream side and the downstream side of the intake air flow in the heater 31 become lower and higher than the reference temperature, respectively. Therefore, the intake air flow amount responsive to the intake air flow direction are detected by detecting the temperature by the flow amount detector 21.

(Third Embodiment)

In a third embodiment, the intake air temperature detector 20 is arranged so that the heat of the heater 30 does not influence the temperature detection operation. It may however occur that the temperature of the semiconductor substrate 11 and the intake air temperature under some engine operating conditions such as a dead soak, hot soak or the like condition. If the semiconductor substrate 11 is solid at a position underneath the intake air temperature detector 20, the temperature of the semiconductor substrate 11 influences the intake air temperature detector 20, thus disabling an accurate detection of the intake air temperature.

For this reason, as shown in Figs. 9A and 9B, a cavity 11b

is formed in the semiconductor substrate 11 at the position underneath the intake air temperature sensor 20 so that the intake air temperature detector 20 is less influenced by the heat of the semiconductor substrate 11 and is enabled to detect the intake air temperature accurately.

(Fourth Embodiment)

In a fourth embodiment shown in Figs. 10A and 10B, a pair of slits 14 are formed in the insulating films 12 and 13 in such a manner that the flow amount detector 21 and the heater 30 are interposed therebetween in the intake air flow direction. The slits 14 restrict the heat of the heater 30 from being transferred to the semiconductor substrate 11. As a result, the electrical power required for the heater 30 to generate heat is reduced.

(Fifth Embodiment)

In a fifth embodiment shown in Fig. 11, the flow amount detector 21 is disposed at the downstream side of the heater 30 with respect to the forward direction of the intake air flow. The relation between the reference temperature and the detection temperature of the flow amount detector 21 does not depend on whether the intake air flow direction is forward or reverse, but depends on whether the flow amount detector 21 is located at the upstream side or the downstream side of the intake air flow. Therefore, the intake air amount is measured even if the flow amount detector 21 is disposed at the downstream side of the heater 30 with respect to the forward direction of the intake air flow.

(Sixth Embodiment)

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In a sixth embodiment shown in Figs. 12A, 12B and 13, the

~~intake air temperature detectors 20 and 22 are disposed at locations where the heat of the heater 30 does not influence the intake air temperature detecting operations. The control circuit is constructed as shown in Fig. 13 so that the temperatures, that is, resistances, of the flow amount detector 21 and the intake air temperature detector 22 as the fluid temperature detector. The potential at the junction 52 between the intake air temperature detector 22 and the fluid amount detector 21 which changes its temperature in response to changes in the intake air temperature does not change. It rather changes in response to the intake air flow amount and the direction of the intake air flow which the fluid amount detector 21. Therefore, the intake air flow direction and the intake air flow amount are measured irrespective of changes in the intake air temperature by applying the potential at the junction 52 and a predetermined fixed potential to one and the other inputs of the amplifier 46, respectively.~~

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(Seventh Embodiment)

It is considered that the circuit of the first embodiment shown in Fig. 2 is constructed to maintain the temperature of the heater 30 constant irrespective of changes in the intake air temperature. If the intake air flow amount detected by the flow amount detector 21 is not influenced by the changes in the intake air flow temperature, the intake air flow direction and the intake air flow amount are measured irrespective of the changes in the intake air temperature by maintaining the input potential applied to the other input of the amplifier 46 at a fixed potential. However, the intake air flow between the heater 30 and the flow

amount detector 21 and the thermal conductivity of the semiconductor substrate 11 actually change with changes in the intake air temperature. Therefore, if the temperature of the heater 30 is set to the fixed temperature, the intake air flow amount detected solely from the temperature detected by the flow amount detector 21 is influenced by changes in the thermal conductivity caused by the intake air temperature.

For this reason, according to a seventh embodiment shown in Fig. 14, a resistor 60 of a fixed resistance between the intake air temperature detector 20 and the junction 50. The range of temperature changes of the heater 30 caused by the temperature changes of the intake air temperature detector 20 is narrowed in the case of using the resistor 60 than in the case of not using the same. Optimizing the resistance of the resistor 60 cancels out the changes in the thermal conductivity caused by the changes in the intake air temperature between the heater 30 and the flow amount detector 21 and the changes in the temperature of the heater 30. As a result, the intake air flow amount and the intake air flow direction are measured solely from the temperature detected by the flow amount detector 21. That is, even if the other input potential of the amplifier 46 is fixed, the intake air flow amount and the intake air flow direction are measured solely from the temperature detected by the flow amount detector 21. The resistor 60 thus compensate for changes in the thermal conductivity between the heater 30 and the flow amount detector 21. The intake air flow amount and the intake air flow direction are also measured even if the resistor 60 is not used in the circuit shown in Fig. 14

by optimizing the characteristics of the resistance changes relative to the temperature of the intake air temperature detector 20.

(Eighth Embodiment)

In an eighth embodiment shown in Fig. 15, the intake air temperature detector 20 in the circuit of the first embodiment shown in Fig. 2 is replaced with a resistor 61 of a fixed resistance so that the temperature of the heater 30 is set to a fixed temperature. The flow amount detector 21, the intake air temperature detector 22 and a resistor 62 of a fixed resistance are connected as shown in Fig. 15, and the potential at the junction between the flow amount detector 2 and the intake air temperature detector 22 is applied to one input of the amplifier 46. The other input potential of the amplifier 46 is fixed.

If the temperature of the heater 30 is set to the fixed temperature, the intake air flow amount detected solely from the temperature of the flow amount detector 21 changes in response to the intake air temperature because of changes in the thermal conductivity caused by the temperature of intake air flowing between the heater 30 and the flow amount detector 21. Therefore, the intake air flow amount responsive to the intake air flow direction is detected irrespective of the intake air temperature, by connecting as shown in Fig. 15 the intake air temperature detector 22 and the resistor 62 having an optimum resistance set in consideration of the changes in the thermal conductivity caused by the intake air temperature, and by applying the potential of the junction 52 and the fixed potential to one input and the other

input of the amplifier 46, respectively. The intake air flow amount responsive to the intake air flow direction is measured even if the resistance 62 is removed from the circuit shown in Fig. 15 by optimally setting the characteristics of the resistance changes of the intake temperature detector 22 relative to temperature.

~~In the foregoing embodiments for implementing the present invention, the intake air flow amount is detected while taking into consideration the intake air flow direction by determining whether the temperature detected by the flow amount detector 21 is higher or lower than the reference temperature. However, the temperature detected by the flow amount detector 21 in response to changes in the distance between the flow amount detector 21 and the heater. For instance, if the flow amount detector 21 is distanced away from the heater, the temperature detected by the flow amount detector 21 may become lower than the reference temperature even if the flow amount detector 21 is located at the downstream side of the heater with respect to the intake air flow in the forward direction. Therefore, it is possible to compare the temperature detected by the flow amount detector 21 and a temperature different from the reference temperature but determined to variably change with the reference temperature based on the distance between the flow amount detector 21 and the heater 30.~~

The present invention may also be applied to a device which measures gas flow amount other than air.